US005881172A

United States Patent [19]

Pintsov

[11] Patent Number: 5,881,172

[45] Date of Patent: Mar. 9, 1999

[54] **HIERARCHICAL CHARACTER RECOGNITION SYSTEM**

[75] Inventor: **David A. Pintsov**, San Diego, Calif.

[73] Assignee: **Mitek Systems, Inc.**, San Diego, Calif.

[21] Appl. No.: **761,845**

[22] Filed: **Dec. 9, 1996**

[51] **Int. Cl.**[6] **G06K 9/68**; G06K 9/70

[52] **U.S. Cl.** **382/227**; 382/310

[58] **Field of Search** 382/224, 226, 382/227, 229, 231, 310, 321, 187

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,589,142	5/1986	Bednar	382/226
4,876,735	10/1989	Martin et al.	382/310
5,418,864	5/1995	Murdock et al.	382/226
5,519,786	5/1996	Courtney et al.	382/310

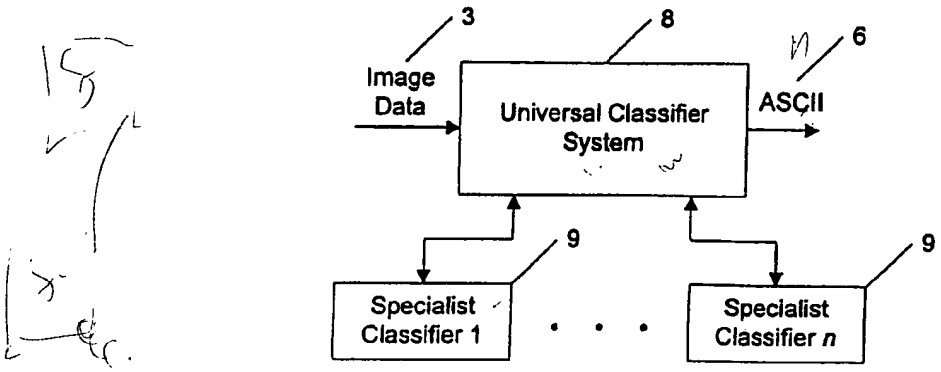
Primary Examiner—Phuoc Tran

Attorney, Agent, or Firm—Fish & Richardson P.C.

[57] **ABSTRACT**

A method and apparatus for hierarchical character recognition processing of ambiguous and noisy characters which produces highly reliable results at high levels of hierarchical processing. The invention first applies a universal classifier system (which may comprise one or more universal classifiers) to input image data, and identifies "suspicious" characters. The image data for suspicious characters is then applied to a "specialist" classifier that is designed to handle only a narrow and well-defined set of recognition cases. This hierarchical processing architecture and method results in increased accuracy of recognition. The method is particularly applicable to handwritten characters and to distorted and noisy machine-printed characters.

3 Claims, 2 Drawing Sheets



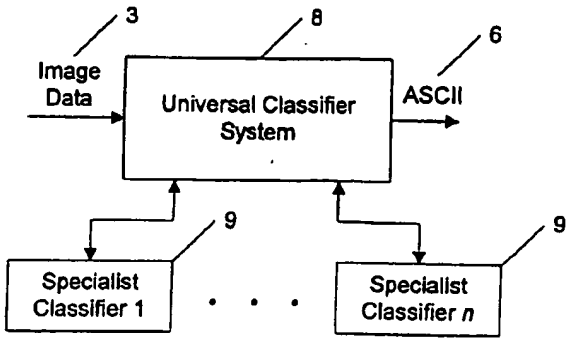

3
8
6
Image Data
Universal Classifier System
ASCII
9
9
Specialist Classifier 1
Specialist Classifier n

FIG. 4

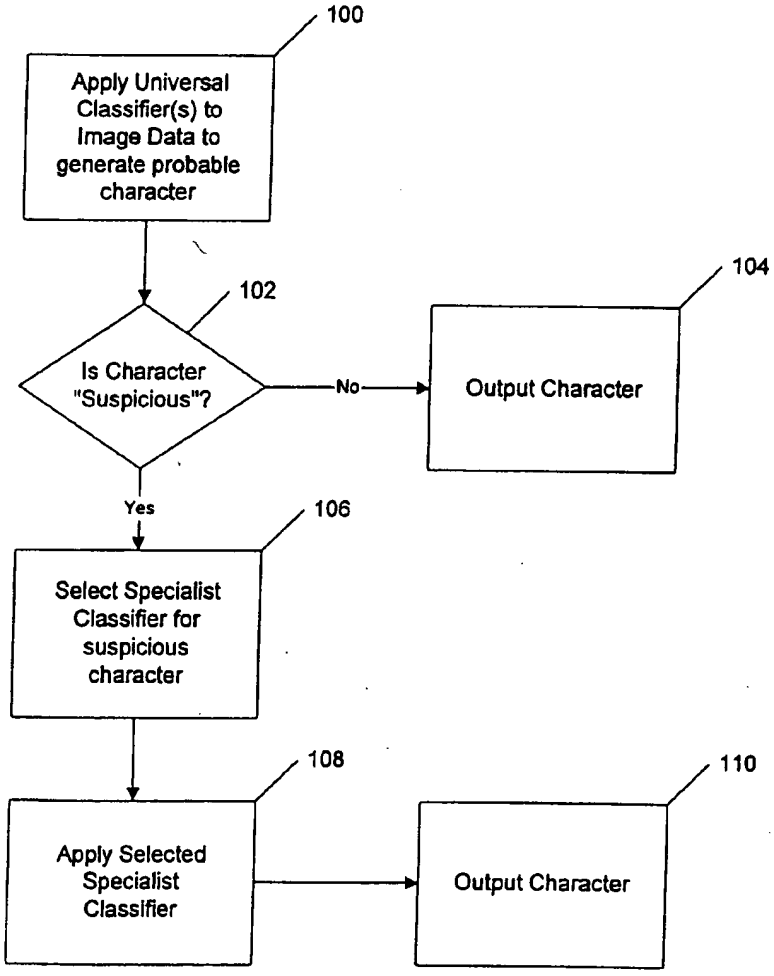

100
Apply Universal Classifier(s) to Image Data to generate probable character
102
Is Character "Suspicious"?
No
104
Output Character
Yes
106
Select Specialist Classifier for suspicious character
108
Apply Selected Specialist Classifier
110
Output Character

FIG. 5

similar characters. Unfortunately, similarity exists even between characters of different classes sufficient to create ambiguities in the recognition of such classes. For example, "I", "l", and "1" have rather similar shapes to a recognition system, as do "S" and "5", "4" and "9", "3" and "8", and several other "ambiguity" classes. The correct identification of such ambiguous characters requires extensive recognition capabilities or the presence of context. The larger the set of characters, the more ambiguity classes it possesses. A universal classifier that is designed to recognize a full set of characters (such as all alphabetic characters and/or all numeric characters) is regularly overwhelmed by morphologically similar characters that humans normally assign to different classes.

To overcome this problem with universal classifiers, the invention employs a hierarchy of "specialist" classifiers, each configured to recognize characters belonging to distinct ambiguity classes. That is, each special classifier is trained or built using known principles to distinguish only the differences between characters in an ambiguity class (e.g., "4" and "9"); the special classifiers are not designed to process characters of other shapes. A classifier of this kind is trained (built) only on a large set of characters that belong to a specific ambiguity class.

The specialist classifiers may be implemented in any desired fashion, using, for example, feature extraction algorithms such as neural networks and syntactic or linguistic algorithms, "nearest neighbor" algorithms, and other algorithms known in the art of character recognition. The distinctive feature of the invention is that the full power of such methods is brought to bear on a specific ambiguity class (e.g., "3" and "8", etc.).

EXAMPLE EMBODIMENT

FIG. **4** is a block diagram showing the basic architecture of the invention. Image data **3** is applied to a universal classifier system **8**, which can comprise one or more universal classifiers of the types known in the prior art. For unambiguous data, the universal classifier system **8** outputs a character code **6**.

However, added to the universal classifier system **8** is the ability to "call" a specialist classifier **9** trained or built to recognize ambiguous image data supplied from the universal classifier system **8**. Any particular specialist classifier **9** is selected based upon the probable identity of a candidate character, as determined by the universal classifier system **8**, and whether the candidate character is "suspicious". A suspicious character may be determined based upon any desired criteria, such as apparent size, the type of character, level of gray in the image of the character, styles of handwriting, prior knowledge that a character candidate has been "surgically" separated from an adjoining character, or upon assignment of a character candidate by the universal classifier system to a predefined character groups known to be ambiguous (e.g., the pair "4" and "9"; the group "I", "l", "1", etc.). The "called" specialist classifier **9** analyzes the image data by performing a recognition algorithm tailored to the candidate character and then outputs a probable character code **6**.

FIG. **5** is a flow chart showing one embodiment of the invention. One or more universal classifiers **8** are applied to image data **3** to generate a probable character (step **100**). A determination is then made as to whether the character is "suspicious". For example, the character may have been recognized by a universal classifier system **8** as probably being a "4". The universal classifier system **8** can be pre-programmed, for example, to always recognize that a "4" is a suspicious character because it is often mistaken for a "9" (particularly with handwritten characters). Thus, the candidate character is part of the ambiguity class containing "4" and "9".

If the character is not suspicious, then the probable character determined by the universal classifier system **8** is output as a code **6** (step **104**). If the character is suspicious (step **102**), a specialist classifier **9** for the suspicious character is selected (step **106**). The selected specialist classifier **9** is then applied to that image data **3** (step **108**) and determines the most probable character to be assigned to the image data **3**. That character is then output as a code **6** (step **110**). Note that the character determined by the selected specialist classifier may be the same character determined as being most probable by the universal classifier system **8**.

Implementation

The invention may be implemented in hardware (digital, analog, or hybrid digital-analog) or software, or a combination of both. However, preferably, the invention is implemented in computer programs executing on programmable computers each comprising at least one processor, a data storage system (including volatile and non-volatile memory and/or storage elements), at least one input device, and at least one output device. Program code is applied to input data to perform the functions described herein and generate output information. The output information is applied to one or more output devices, in known fashion.

Each program is preferably implemented in a high level procedural or object oriented programming language to communicate with a computer system. However, the programs can be implemented in assembly or machine language, if desired. In any case, the language may be a compiled or interpreted language.

Each such computer program is preferably stored on a storage media or device (e.g., ROM or magnetic diskette) readable by a general or special purpose programmable computer, for configuring and operating the computer when the storage media or device is read by the computer to perform the procedures described herein. The inventive system may also be considered to be implemented as a computer-readable storage medium, configured with a computer program, where the storage medium so configured causes a computer to operate in a specific and predefined manner to perform the functions described herein.

In one implementation of the invention, use of specialist classifiers improved the error-rate by about 40% compared to the same system without specialist classifiers.

A number of embodiments of the invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. Accordingly, it is to be understood that the invention is not to be limited by the specific illustrated embodiment, but only by the scope of the appended claims.